Remarks

Claims 1-9, 13-19, and 28-46, and 56-61 are pending in the application. Claims 10-12, 20-27, and 47-55 were withdrawn from consideration based on an election of species requirement. No new matter has been added by virtue of this response. In this response applicant presents textbook evidence. Reconsideration of the application in view of this response is requested.

Claim Rejections-- 35 U.S.C. § 103(a)

In the first response after final, applicant presented argument that the Examiner found not persuasive. Applicant has reviewed numerous text books on the subject of electronically tunable capacitors (also known as varactors and as tuning diodes), and attaches to this response copies of pages showing that **experts in the field were teaching against the idea of claims 1 and 40 and claims dependent thereon**.

In section 12.2.3, entitled "Varactor diodes," the book Introduction to Microwave Circuits by R. J. Weber, published by Wiley Interscience, New York, 2001, pages 286-287 [BOK409] states (see attached copy):

> A varactor (variable capacitor) diode is a semiconductor junction diode. The parasitic series resistance of a varactor diode is of primary consideration in maximizing he Q of the diode. The depletion region of the semiconductor junction acts as a capacitor. The dc voltage across the diode determines the depletion width and thus the depletion capacitance of the varactor. The **RF voltage** across this depletion region **must be small** with respect to the dc voltage across the diode **if harmonic generation is to be minimized**. However, often harmonic generation is the desired result in frequency-multiplier circuits.

Weber teaches the signal **must** be small when varactor diodes are used if harmonic generation is to be minimized (as in an amplifier). Thus, Weber clearly teaches against using varactor diodes for amplifying a high voltage signal. In addition to small-signal applications where harmonic generation is to be avoided, Weber notes that the varactor diode can also be used for harmonic generation, such as in frequency multipliers, which take advantage of the non-linear feature of the varactor. Thus, Weber, teaches against the idea of a power amplifier coupled to an electronically tunable output network in which the output network includes an electronically tunable reactive component.

In Section 2-1-4, entitled "Tuning Diodes," the book RF/Microwave Circuit Design for Wireless Applications, by U. L. Rohde and D. P. Newkirk, Wiley Interscience, 2000, New York, also teaches against using varacters (or tuning diodes as they are called in this book) for amplifying large signals. Beginning on page 153, the section provide a detailed discussion of tuning diodes. On p. 168 the authors discuss distortion products. They note that in case of frequency multiplier, distortion products are desirable, but "for other applications, **such as tuning-diode-tuned linear circuits, distortion products are extremely undesirable**, and in some instances the end product specification may set a maximum limit on the distortion products allowed." The authors present several problems, such as cross modulation, intermodulation, and harmonic distortion, that limit use of a tuning diode, even for small signal amplifiers.

Rohde and Newkirk then show several circuits (pages 170, 172) that cancel some (but not all) of the distortion products. Thus, the distortion products clearly remain a problem, even in the small-signal applications that they are discussing. And even for the small signal applications the partial solution Rohde and Newkirk provide is more complex than merely substituting a single varactor for a mechanically tuned capacitor.

On p. 186, Rohde and Newkirk explain how electronically tunable capacitors work, and then state clearly the limits of such devices:

> In normal operation, the sum of the tuning voltage and the alternating signal voltage of the resonant circuit is applied to the tuner diode. The bias, and thus the capacitance, of the turner diode therefore varies at the rhythm of the alternating voltage. Due the nonlinear character of the capacitance versus voltage curve, voltage distortions and capacitance shifts are inevitable, and these must be kept within adequate limits. **This is done by maintaining the ac applied to the diode(s) at a sufficiently low ac amplitude** and by choosing an adequate minimum value for the tuning voltage."

Thus Rohde and Newkirk teach against the idea of providing a high level signal to their tuning diodes. One of ordinary skill in the art would conclude that tuning diodes were suitable only for small-signal use, and even there, distortion and harmonics are a problem that must be avoided. Thus, Rohde and Newkirk teach against the idea of a power amplifier coupled to an electronically tunable output network, in which the output network includes an electronically tunable reactive component.

This conclusion is further supported in Section 3-6 of Rohde and Newkirk, which discusses voltage-tuned filters at some length. The discussion for filters demonstrates further why one of ordinary skill would be averse to using the tuning diodes for power amplifiers. Fig. 3-148 shows a standard plot of output versus input. The top curve 1F is

the desired output v. input which follows a straight line from -20 dBm to about -10 dBm input level, which is equal to only about 100 microwatts. For an input of -20 dBm, or 10 microwatts, the distortion is well below the signal level, as shown by the straight line characteristic of curve 1F along the left hand portion of the curve. Above -10dBm the solid line is the actual output v. input which drops below the dotted straight line, which is the ideal linear characteristic. The difference between these curves is the magnitude of the distortion. Thus, above -10 dBm the distortion becomes significant and causes the actual output (solid line) to differ from the ideal linear output (dotted line), and that difference increases with input power level above only this -10dBm level.

The bottom curve, IM3, is one of many distortion products produced. for a typical VHF tunable filter. Here it is seen that this distortion product increases rapidly with signal level, and it makes the filter unsuitable for use certainly above a small input level.

Furthermore, the distortion increases rapidly with signal level and is equal to the signal level at a power of only 0 dBm or about 1 mW (one milliwatt), hence Rohde and Newkirk teach that the tunable filter is suitable only for low-power, small-signal operation. One of ordinary skill would look at the intercept point, the point where the signal and the distortion are equal. That occurs for this device at only about 0 dBm or about 1mW. Thus, this filter is good for no more than 1mW of signal.

Fig. 3-149 shows a so-called "high-dynamic range" tunable filter. Its distortion characteristics, shown in Fig. 3-151 shows distortion beginning at 10 dBm which is equal to 10mW, which is still a small signal. The intercept point where linear portions of the two curves meet is at a signal level of +18 dBm (63 mW). At this point the signal and the distortion product are of equal amplitude. One would want to operate 20dBm lower than this point to keep distortion and harmonics to acceptable levels. And this is much less than the input power amplified by a power amplifier. To achieve a realistic distortion requirement of -30 dBc (distortion 30 dB lower than the signal), the maximum signal level is +3 dBm (only 2 mW), which, despite the name "high dynamic range" given by Rohde and Newkirk, is still clearly low-power, small-signal operation.

The discussion of varactor diodes in the book by F. Losee, RF Systems, Components, and Circuits Handbook, Artech House, 1997, Boston, is typical of many books in this field. In Sec. 17.6, on p.503, Losse says that varactors find application in frequency modulation and oscillator tuning, as well as frequency multipliers. The first two applications are small-signal. As noted in Sec. 6.3, p. 163, frequency multipliers make use of the "nonlinearity inherent in any semiconductor diode." There is no teaching or suggestion of using varactors for power amplification.

Following is a list of ten other books that show similar applications, all of which provide only small signal level application for amplification. The only other case

discussed is where the harmonics are desired, and these are not for power amplification.

BOOKS THAT MENTION VARACTORS

All of the following books discuss the use of varactors in small-signal applications such as oscillators, modulators, and phase shifters, and in some cases, frequency multipliers. None teach or suggest the idea of providing varactors for amplifying large signals.

H. L. Krauss, C. W. Bostian, and F. H. Raab, Solid State Radio Engineering. New York: Wiley, 1980.

P. B. Kenington, High Linearity RF Amplifier Design. Norwood, MA: Artech, 2000.

P. Vizmuller, RF Design Guide: Systems, Circuits, and Equations. Norwood, MA: Artech, 1995.

S. C. Cripps, RF Power Amplifiers for Wireless Communication. Norwood, MA: Artech, 1999.

S. C. Cripps, Advanced Techniques in RF Power Amplifer Design. Boston, MA: Artech House, 2002. Cripps is a top power-amplifier expert but mentions varactor diodes only in connection with small-signal predistorter.

S. A. Maas, The RF and Microwave Circuit Design Cookbook. Boston: Artech House, 1998.

U. L. Rohde, Microwave and Wireless Synthesizers. New York: Wiley, 1997.

W. H. Hayward, Introduction to Radio Frequency Design. Englewood Cliffs, New Jersey: Prentice-Hall, 1982.

G. D. Vendelin, Design of Amplifiers and Oscillators by the S-Parameter Method. New York: Wiley, 1982.

T. K. Ishii, Ed., Handbook of Microwave Technology, Vol. 1, Components and Devices. San Diego: Academic Press, 1995.

In conclusion, various text books show that some experts in this field teach against the idea of a power amplifier coupled to an electronically tunable output network, said output network including an electronically tunable reactive component or they show

only small-signal applications. Other experts simply do not teach or suggest the idea.

The Examiner rejects claim 1-9, 13-19, and 28, 30-34, 37, 38, 40-46, and 56-61 under 35 U.S.C. § 103(a), as being unpatentable over Sokal in view of Shenai. The Examiner states that "claims 1-9, 13-19,28,30-34,37,38,40-46, and 56-61 are rejected under 35 U.S.C. 103(a) as being unpatentable over Sokal et al. 3,919,656 (Sokal) in view of Shenai et al. 5,914,513 (Shenai). Figures 8a and 8b of Sokal discloses a power amplifier having a power amplifier Q with a tuned output network 9. Note that the driver 2 clearly adjusts/modulates the signals to the power amplifier, as this is what a driver does by definition. The reactive components are adapted to be tuned to a selected frequency by the tuning signal applied to the tuning input. Sokal teaches that variable reactive elements can be utilized in the filter **but is silent on the exact variable element**. As would have been well known to one of ordinary skill in the art, an electronically controlled reactive element is a conventional means for forming a variable reactive element. In fact Shenai of record discloses such a conventional means and is in fact an art recognized equivalent to C4 in Sokal. Accordingly, it would have been obvious to one of ordinary skill in the art at the time of the invention to use electronic controlled reactive elements because, as the Sokal reference is silent on the exact variable reactive element, any art-recognized equivalent variable reactive element would have been usable therewith such as that of Shenai."

As pointed out by the Examiner in FIGS. 8a, 8b Sokal does not teach or suggest electronically tunable reactive devices. He does not describe his variable capacitor or inductor as having capacitance or inductance that varies with bias and with signal level, as would be the case for electronically variable reactances subject to large input signals. In view of the teachings of the text books cited, one of ordinary skill in the art would understand his variable capacitor and variable inductor as being standard mechanically variable reactive elements, as found in many ordinary tunable electronic devices, rather than electronically variable capacitors.

In a mechanically variable capacitor, the plates are moved to change the capacitance. The capacitance depends on the position of the plates but in any position the capacitance is independent of the applied voltage. In essence, the variable capacitor becomes a fixed capacitor once the operator stops moving the plates. Consequently, one can apply a signal of any amplitude (short of breakdown, of course) and will see the same capacitance. Because in any position of the plates the capacitance is fixed and independent of the applied signal voltage, there will be **no distortion** of the applied waveform by the mechanically variable capacitor.

As described in the textbooks cited, in an electronically variable capacitor, the capacitance depends upon the instantaneous voltage (sum of bias voltage and instantaneously varying RF voltage) applied to it. Unlike a mechanically variable

capacitor, an electronically variable capacitor does not become a fixed capacitor after one changes its value. While a mechanically variable capacitor will provide a capacitance that is independent of signal strength, this is not true for an electronically variable capacitor. Thus, while there is little difference in operation between small-signal and large-signal operation for mechanically variable capacitors, there is an important difference in operation for electronically variable capacitors.

In small-signal operation, the bias voltage is significantly larger, perhaps ten or more times larger, than the RF voltage. The RF voltage has little effect upon the capacitance of the electronically variable capacitor, which is substantially controlled by the much larger bias voltage. Thus, for small signals, the capacitance is essentially fixed as far as the RF is concerned, so the output RF waveforms are negligibly distorted by capacitance variation, and the harmonics produced are low. Previous uses for electronically variable reactive components are in small-signal applications in which the amplitude of the RF signal is a small fraction of the bias voltage or bias current so nonlinear variation is insignificant. This small signal mode of operation is used in the voltage-controlled oscillators, phase shifters, and small-signal tunable filters.

In large-signal operation, the RF voltage is now an appreciable fraction of the bias voltage (more than 1/10). The capacitance of the electronically variable capacitor now varies in response to the varying large signal RF voltage. This means that capacitance of the electronically variable capacitor varies within the RF cycle as the RF swings positive and negative. While the bias voltage is still used to control the capacitance, the average capacitance now depends upon both the bias and the amplitude of the RF. And the instantaneous capacitance is varying with the RF input signal. The output RF waveform is significantly distorted because of the variation of the instantaneous capacitance with time varying magnitude of the input RF signal, and therefore, significant harmonics are produced.

Varactor diodes have been used with large-signals for intentional production of those harmonic signals. In a frequency doubler, for example, a signal of frequency f is driven into the varactor through one filter and a signal at frequency 2f is extracted from the varactor through another filter. This is frequency multiplication, not power amplification. But this use illustrates the point that one of ordinary skill would be averse to using an electronically tunable capacitance for a power amplifier.

The electronically variable inductor has an analogous situation. It is controlled by current. The magnetic flux that circulates in the inductor is produced is a sum of bias and RF currents, leading to the same effects for electronically tunable inductors that would not occur for mechanically tunable inductors.

Thus, in providing for a power amplifier, that amplifies input signals having large

signals, it would not be obvious to substitute electronically tunable capacitors and inductors for mechanically tunable capacitors and inductors. One of ordinary skill in the art would have expected that using an electronically variable reactive tuning device would result in signal distortion and production of significant power at harmonic frequencies, resulting in non-linear amplification and inefficient production of power at the desired frequency. One would conclude that linear amplification would be impossible.

Therefore, applicant would respectfully ask the Examiner to consider that one cannot simply drop an electronically variable reactance into the place of a conventional mechanically tuned reactance in a power-amplifier circuit. If in Sokal's power amplifier, mechanically variable capacitor C4 in FIG. 8b was replaced with Shenai's MMDC, the wave form would be distorted and significant harmonic power would be produced at the output, reducing the useful efficiency of the amplifier significantly. One of ordinary skill would recognize that merely substituting Shenai's electronically variable capacitor for Sokal's mechanically variable capacitor won't work. Thus, it is not obvious to combine the references. For the electronically variable capacitor to work in Sokal's circuit recognition that the problems can be overcome and additional invention are needed. It was applicant who provided that recognition and that additional invention.

While one of ordinary skill would have thought the suggestion of an electronically tunable power amplifier unworkable because of the nonlinear effects produced by variation of the electronically variable components with signal level, as described in the attached books, applicant recognized that the non-linearity problem posed by electronically variable reactances could be overcome and that such electronically variable reactances could be used in a power amplifier. Applicant was first to recognize that electronically variable reactance behave adequately as reactive elements in an amplifier, and that a substantial portion of unwanted harmonics could be filtered to provide a desirable output.

In addition, even without the concern about non-linear effects, the present applicant recognized that one cannot merely drop Shenai's MMDC into Sokal's circuit and expect the circuit to work in a power amplifier. The present applicant provided additional circuit components to make the electronically variable reactances work in a power amplifier. As shown in FIG. 2 of the present application, he recognized that dc-blocking 31, 36 for electronically tunable capacitors 32, 37 and bias-feed components 33, 38, permit bias and control to be applied to the tunable component in a way that does not interfere with the high-power RF signal. Simlarly, dc-blocking 55A, 55B, and 55C for electronically tunable inductor 56, and bias-feeds 33 53, 57 are shown in FIG. 4. Also, dc-blocks 236, 237, 238, 239 for electronically tunable capacitors 232, 233, 234, bias-feed components 240, and RF-bypass 242, 246 are shown in FIG. 22. While these components do not overcome the problem of non-linearities, they do show that the combined references were not enabling as to how to provide the electrically tunable

reactive element in Sokal's circuit. Further invention was needed just to make it work, even without addressing the non-linearity issue, and the present inventor was first to provide that further invention.

Second, the present inventor further realized that the nonlinearities were not entirely a show-stopper. For example, the present inventor realized that a harmonic component that is 20 percent of the amplitude of the fundamental causes significant distortion of the waveform, but constitutes no more than 4 percent of the power. Thus one can operate a power amplifier with an electronically variable reactance that is inherently nonlinear and at the most have a small reduction in the efficiency and output at the fundamental frequency of interest.

Third, the present inventor disclosed techniques for reducing or avoiding effects of the non-linear electronically variable reactive element. His novel solution was to use conventional reactances to trap the harmonics so that they don't reach the output or cause interaction of two nonlinear devices. He included at least one conventional component between the electronically tuned component and output to keep harmonic levels down. Thus, the output signal has reduced effect from the non-linear portion of the electronically tunable reactance, and there is minimal distortion of the output signal.

For example, a conventional inductor presents a high impedance to the harmonics, thus preventing significant harmonic current from flowing through. A conventional capacitor analogously presents a lower impedance to a harmonic, thus shunting it to ground.

One implementation of this technique is shown in FIG. 3, where conventional tuning capacitors 41 and 45 isolate electronically variable inductor 42 from output 28 and active device 20.

Another implementation is in FIG. 4, where conventional tuning capacitor 51 isolates electronically variable transmission lines 52 and 56 from active device 20.

In FIG. 7, fixed filter 70 isolates electronically tuned filter 11 from load 19.

In Fig. 15, conventional capacitor 130 and inductor 131 isolate electronically tuned filter 132 from active device 20.

In Fig. 22, conventional tuning inductor 230 isolates the voltage-variable capacitance of MOSFET 232 from the voltage-variable capacitance of MOSFET pair 233 and 234. Conventional tuning inductor 231 isolates the voltage-variable capacitance of MOSFET pair 233 and 234 from output 222 (which is coupled through transformer 221). Fig. 22 is the best example and represents an actual circuit which the present

inventor built.

These figures illustrate a few of many possible configurations. Alternatively, the load may include a reactance that serves this purpose (e.g., the inductance in a loud speaker).

Thus, the rejections of claims 1-9, 13-19, and 28, 30-34, 37, 38, 40-46, and 56-61 under 35 U.S.C. § 103(a), as being unpatentable over Sokal in view of Shenai have been traversed.

As to claim 2, absent the invention described in the present application it would not be obvious how to adapt the output network to be tuned to a selected frequency in view of the capacitance or inductance of the power amplifier itself varying with the signal. It was the present inventor who taught how to accomplish this, as described herein above.

As to claim 3, absent the invention described in the present application it would not be obvious how to match load impedance in view of the capacitance or inductance of the power amplifier itself varying with the signal. It was the present inventor who taught how to match load impedance with an electronically variable reactance that itself varies with the signal, as described herein above.

As to claim 4, absent the invention described in the present application it would not be obvious how to produce a modulated signal with the output network in view of the capacitance or inductance varying with the signal. Applicant would note that prior-art power amplifiers produce amplitude-modulated signals by either (a) amplifying a signal that is already amplitude modulated or (b) varying the supply voltage. However, there was no teaching or suggestion in the references or in any other prior art of which the applicant is aware, that the electronically tuned output network can introduce modulation into the signal, as described in claim 4. This is entirely new, and this technique has significant advantages in both bandwidth and amplifier efficiency, as described in the specifications section (starting at the middle of page 10 under "modulation" and continuing through page 17). The process is shown clearly in Fig. 9 and to a lesser extent in Fig. 5. One skilled in the art would not have envisioned the use of conventional variable reactances for modulation of the amplifier because they are far too slow with their rotating shafts and motors, since modulation requires changes at rates from several kilohertz to tens or hundreds of megahertz. These rates can be achieved by electronically variable components, but not by conventional components, and applicant was first to teach how to accomplish modulation using electronically variable reactances.

As to claim 5, which is dependent on claim 4, absent the invention described in the present application it would not be obvious how output network can be adapted to

provide a power-amplifier load-impedance locus that substantially maximizes power-amplifier average efficiency. Applicant would respectfully ask the Examiner to consider that this goes beyond maximizing the efficiency for one particular output as one would by adjusting to match a load impedance. Rather it is selecting a locus of impedances that gives a good average impedance for a modulated signal. In accomplishing this selection, the locus must be a good compromise between providing amplitude variation and efficiency.

It is believed that the claims are in condition for allowance. Therefore, applicant respectfully requests favorable reconsideration. If there are any questions please call applicant's attorney at 802 864-1575.

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